Reconnection physics and fast flux closure during simulations of Coaxial Helicity Injection in NSTX/NSTX-U

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Magnetic reconnection, which energizes many processes in nature, has been shown to have a fundamental role in the plasma start up and current formation in NSTX/NSTX-U. Through resistive MHD simulations, it is demonstrated that during transient Coaxial Helicity Injection (CHI) discharges at high Lundquist number, the elongated current sheet formed through a Sweet-Parker forced reconnection process [1] breaks up, and a transition to spontaneous reconnection (plasmoid instability) occurs. [2] Consistent with theory, fundamental characteristics of the plasmoid instability are demonstrated through NIMROD MHD simulations of transient CHI experiments in the NSTX. Simulations have been performed in a realistic geometry with a toroidal guide field and using experimental NSTX poloidal coil currents. Motivated by the simulations, experimental camera images have been revisited and suggest the existence of reconnecting plasmoids in NSTX. As CHI is a promising candidate for plasma start-up and may ultimately also have the potential for steady-state current drive, it is thus important to understand the CHI physics to be able to correctly model it in simulations of NSTX/NSTX-U and to be able to extrapolate its viability to a reactor. Our simulations show that plasmoid-mediated reconnection may be the leading mechanism for fast flux closure.

A large-volume flux closure during transient CHI experiments in NSTX-U is also demonstrated through MHD simulations. Several major updates, including the location of CHI poloidal coils, are planned to improve the CHI start-up phase in NSTX-U. Simulations in the NSTX-U configuration with fixed coil currents show that with strong flux shaping the injected open field lines (injector flux) could rapidly reconnect and form a large volume of closed flux surfaces. This is achieved by driving parallel current in the injector flux coil and oppositely directed currents in the flux shaping coils to form a narrow flux footprint and push the injector flux. As the helicity and plasma are injected into the device, the oppositely directed field lines in the injector region (a) are forced to reconnect and form a current sheet (b) or spontaneously to reconnect when the elongated current sheet becomes MHD unstable. Simulations in NSTX-U also show that the magnetic pressures around the enclosed flux surface would support a steady configuration to allow a good start-up equilibrium after the injector voltage is turned off. Supported by DOE-FG02-12ER55115.

[1] F. Ebrahimi et al. Phys. Plasmas 20, (090702) 2013.

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